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(54) **STACKED SEMICONDUCTOR DIE ASSEMBLIES WITH THERMAL SPACERS AND ASSOCIATED SYSTEMS AND METHODS**

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See application file for complete search history.

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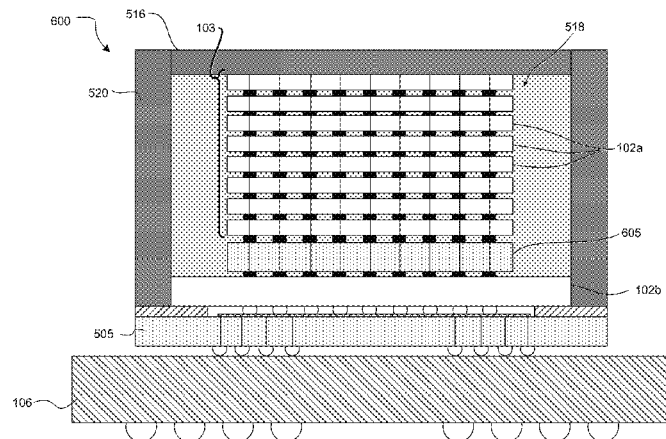
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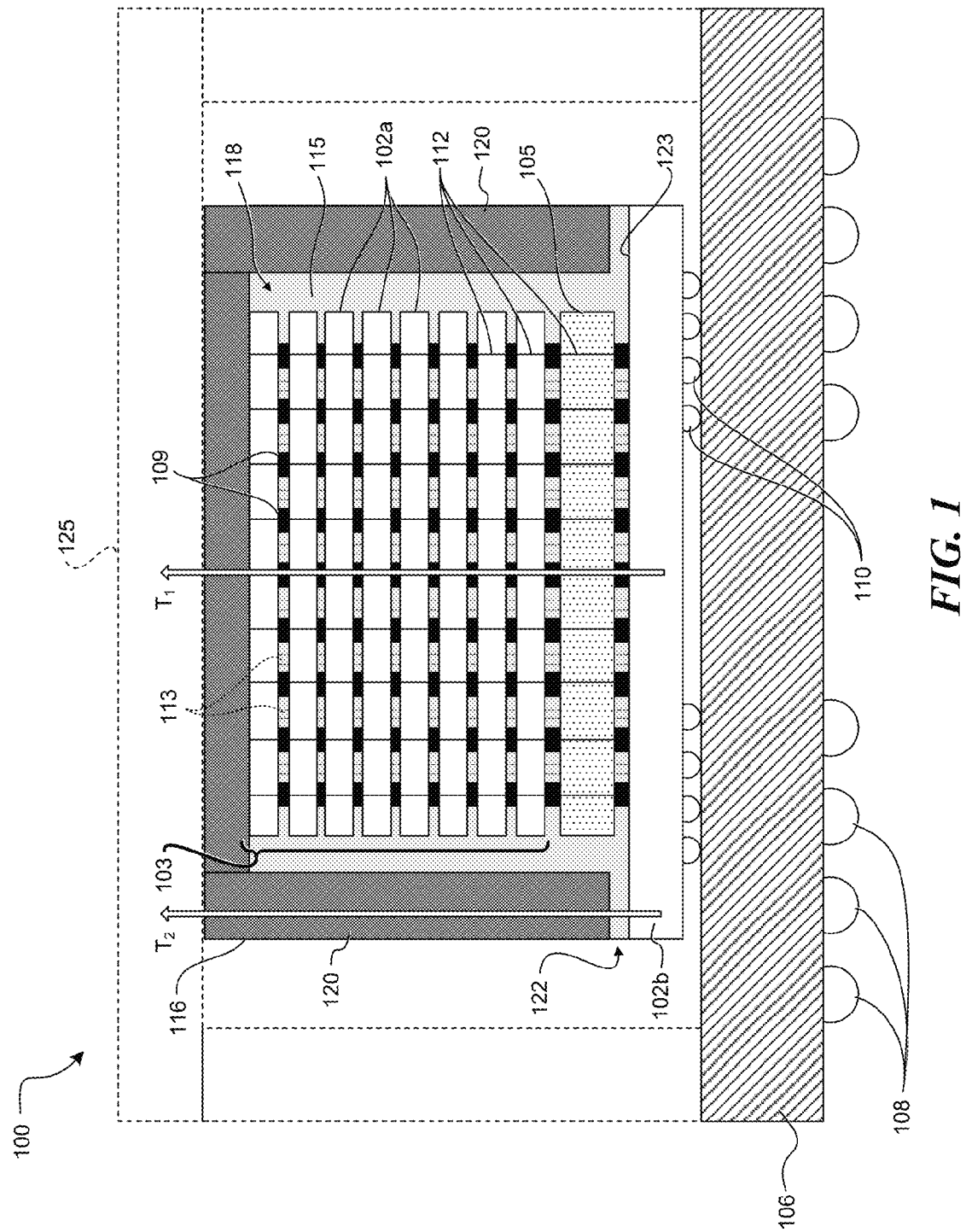
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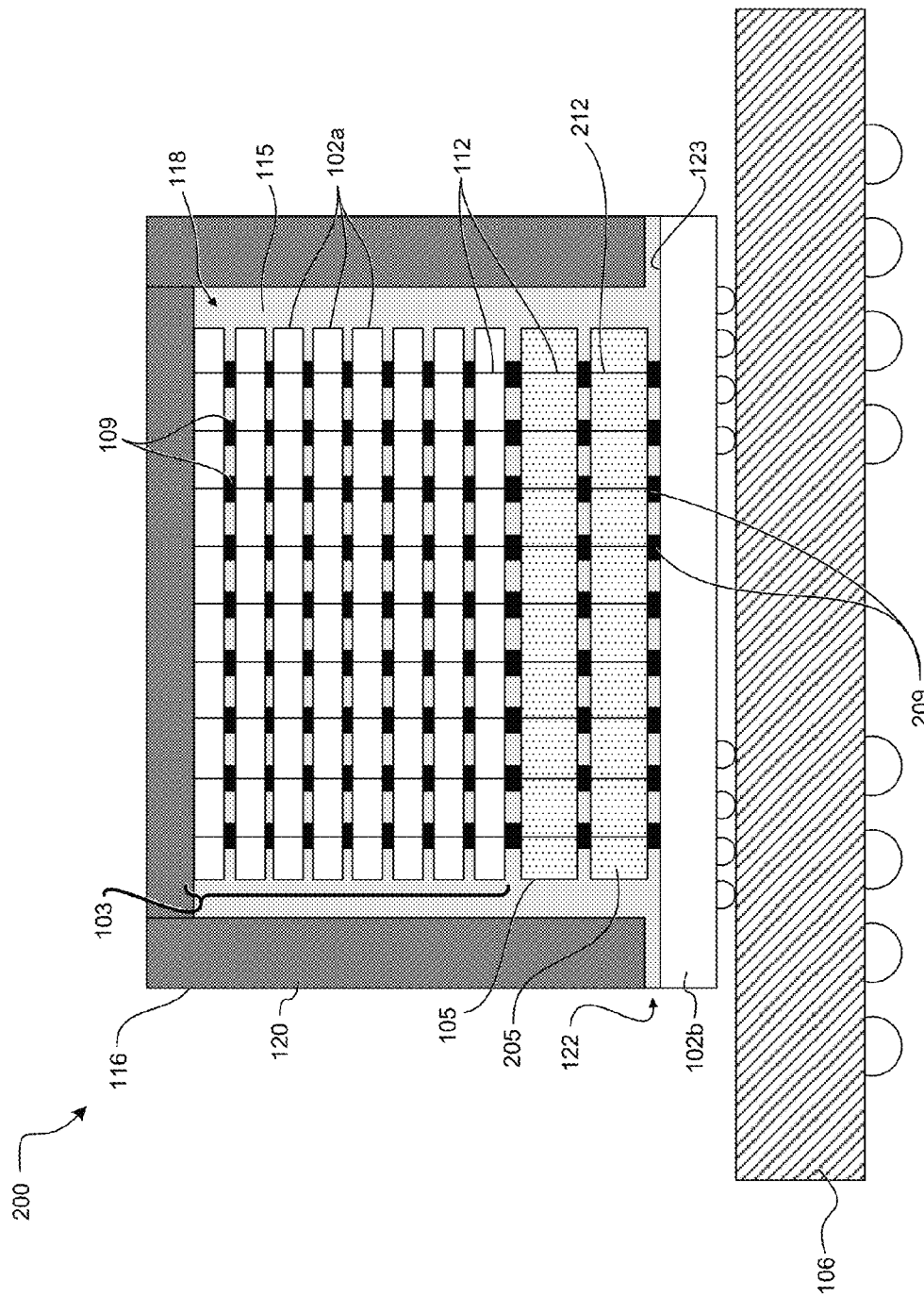
(57) **ABSTRACT**

Stacked semiconductor die assemblies with thermal spacers and associated systems and methods are disclosed herein. In one embodiment, a semiconductor die assembly can include a thermally conductive casing defining a cavity, a stack of first semiconductor dies within the cavity, and a second semiconductor die stacked relative to the stack of first dies and carried by a package substrate. The semiconductor die assembly further includes a thermal spacer disposed between the package substrate and the thermally conductive casing. The thermal spacer can include a semiconductor substrate and plurality of conductive vias extending through the semiconductor substrate and electrically coupled to the stack of first semiconductor dies, the second semiconductor die, and the package substrate.

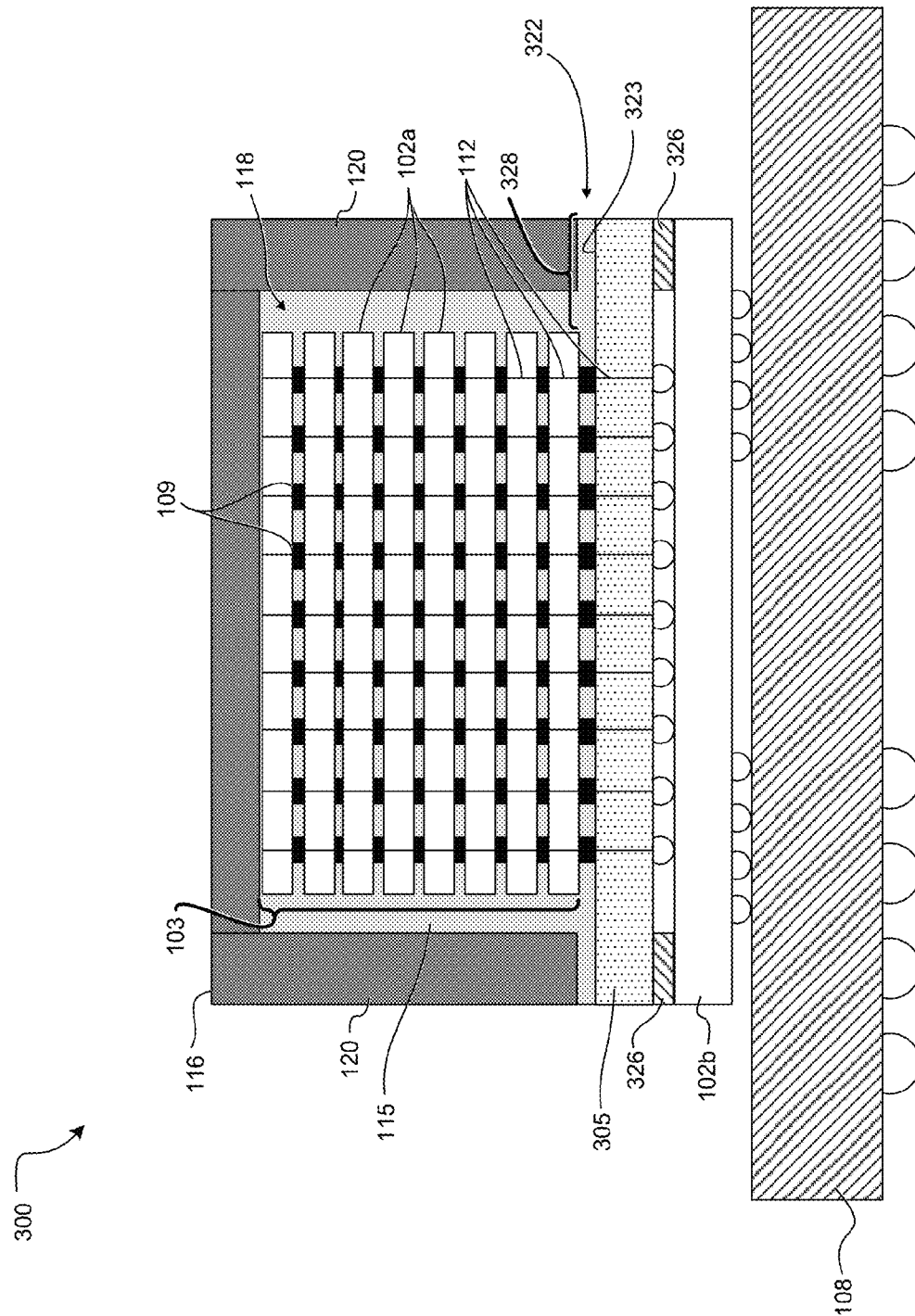
**21 Claims, 7 Drawing Sheets**







**FIG. 2**



**FIG. 3**

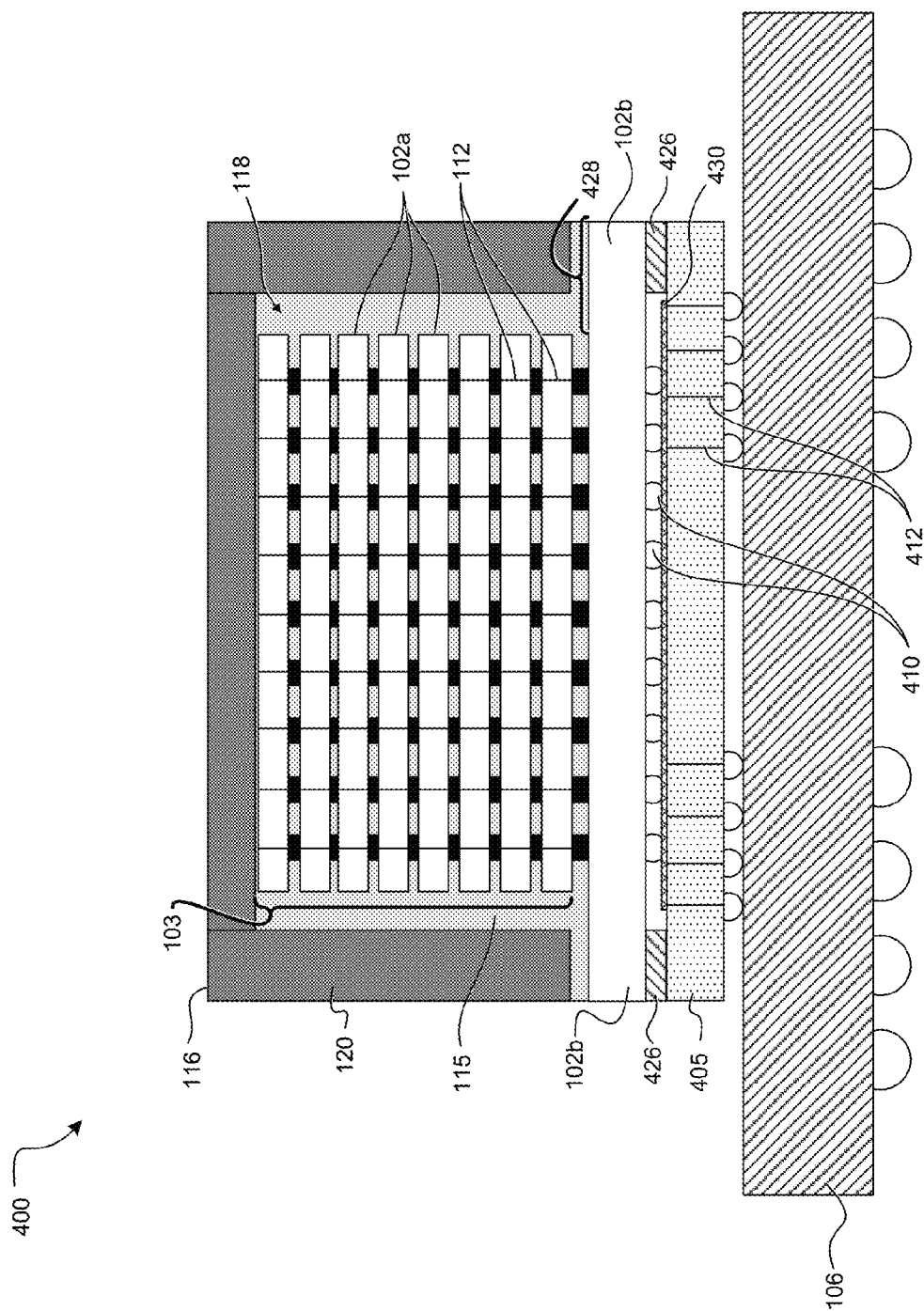
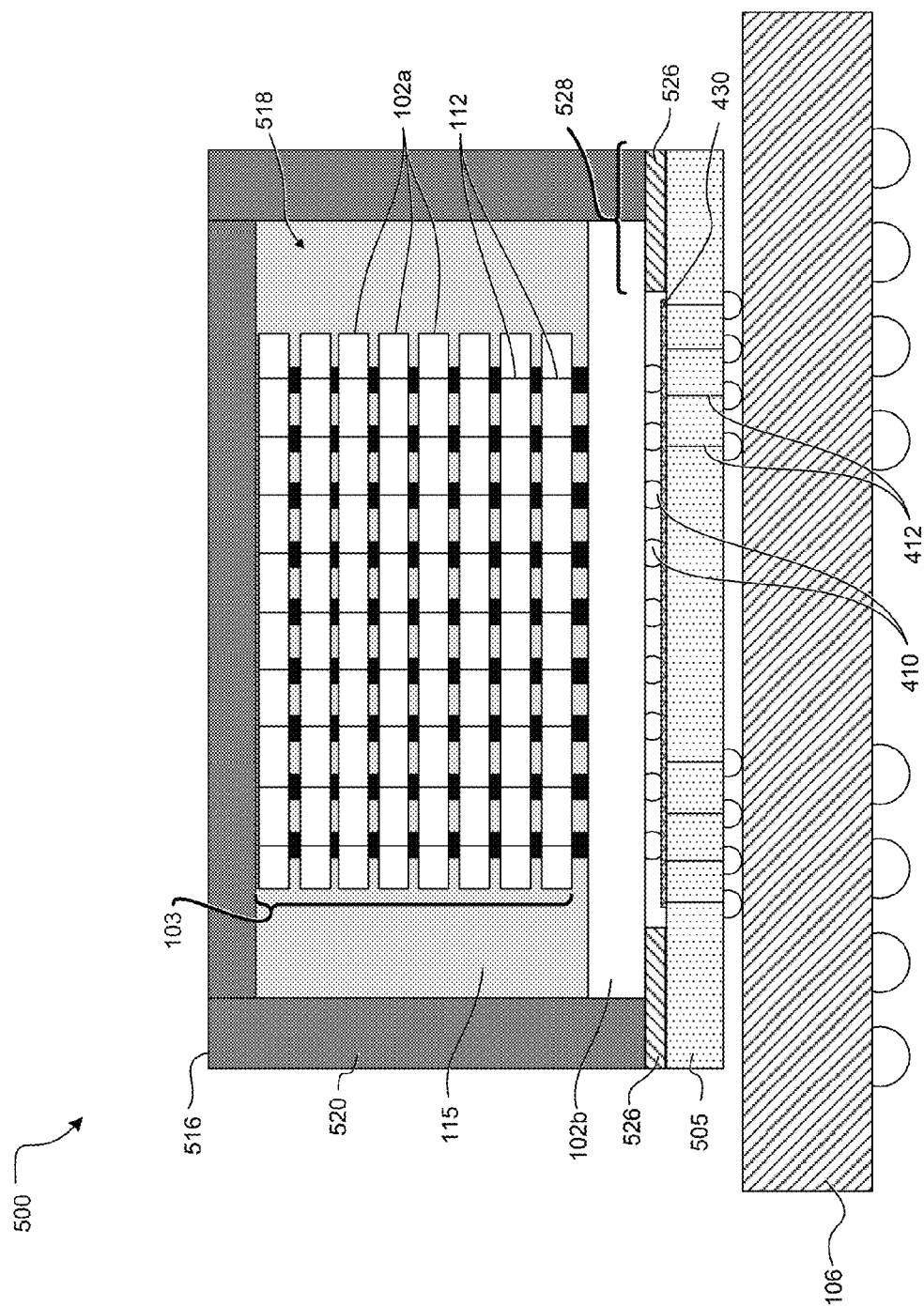


FIG. 4



**FIG. 5**

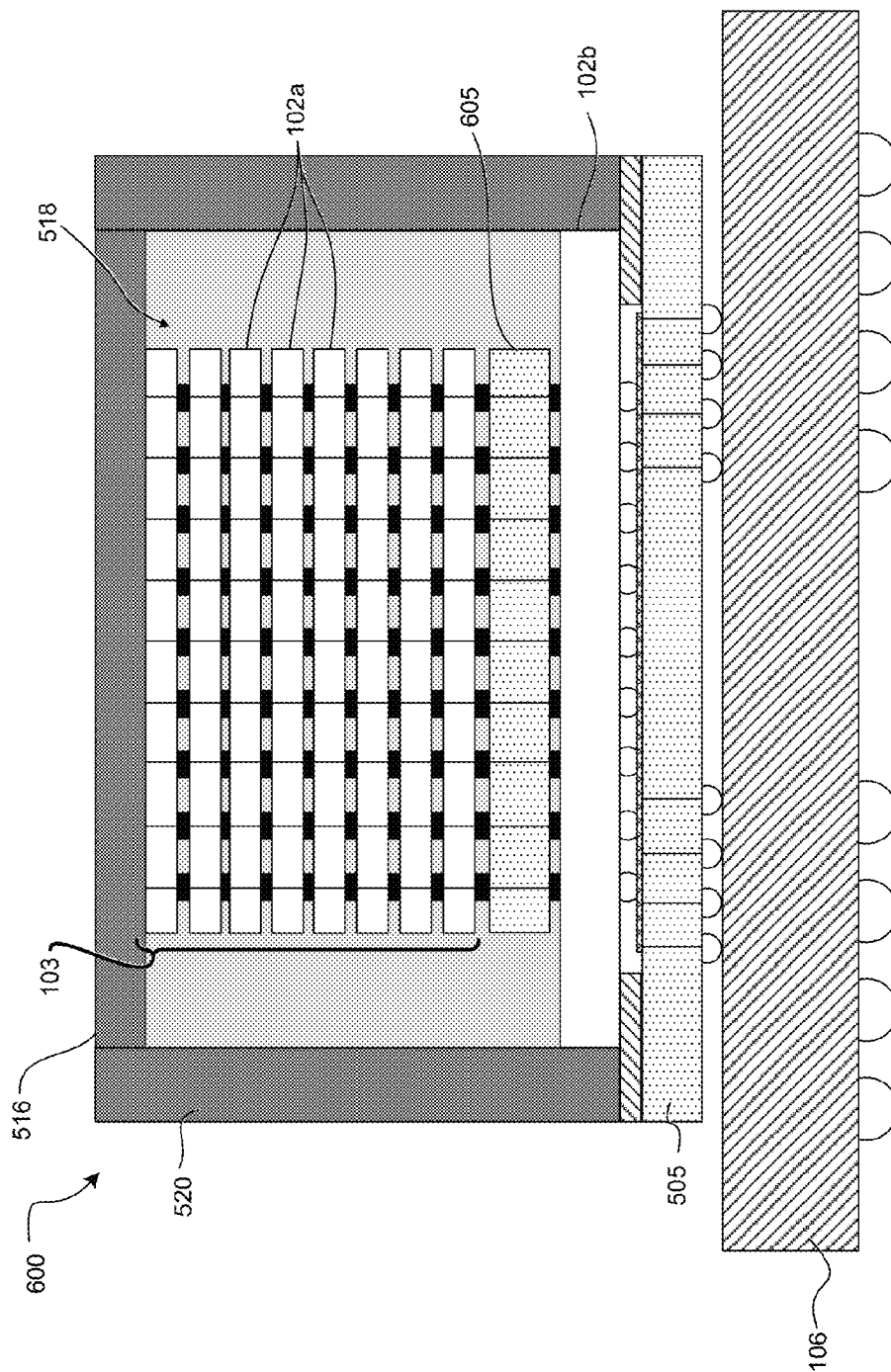
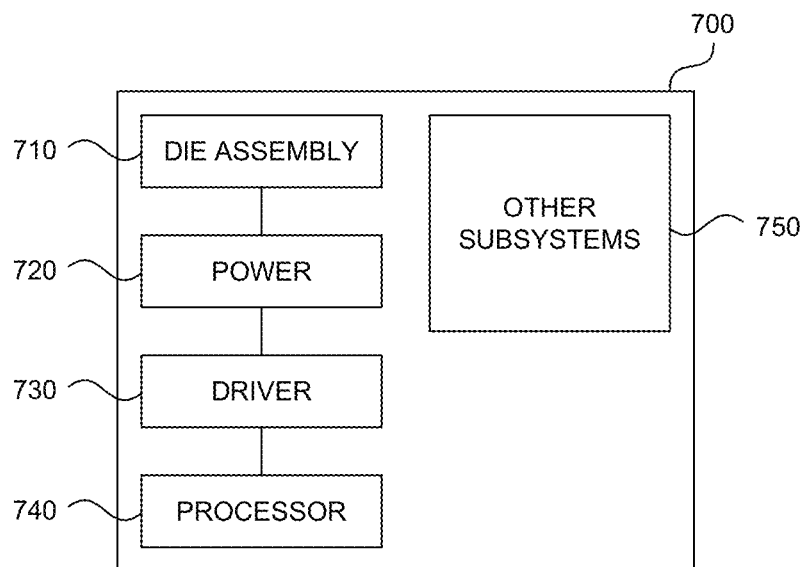


FIG. 6

**FIG. 7**



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# STACKED SEMICONDUCTOR DIE ASSEMBLIES WITH THERMAL SPACERS AND ASSOCIATED SYSTEMS AND METHODS

## TECHNICAL FIELD

The disclosed embodiments relate to semiconductor die assemblies and to managing heat within such assemblies. In particular, the present technology relates to stacked semiconductor device assemblies with thermal spacers and associated systems and methods.

## BACKGROUND

Packaged semiconductor dies, including memory chips, microprocessor chips, and imager chips, typically include a semiconductor die mounted on a substrate and encased in a plastic protective covering. The die includes functional features, such as memory cells, processor circuits, and imager devices, as well as bond pads electrically connected to the functional features. The bond pads can be electrically connected to terminals outside the protective covering to allow the die to be connected to higher level circuitry.

Market pressures continually drive semiconductor manufacturers to reduce the size of die packages to fit within the space constraints of electronic devices, while also pressuring them to increase the functional capacity of each package to meet operating parameters. One approach for increasing the processing power of a semiconductor package without substantially increasing the surface area covered by the package (i.e., the package's "footprint") is to vertically stack multiple semiconductor dies on top of one another in a single package. The dies in such vertically-stacked packages can be interconnected by electrically coupling the bond pads of the individual dies with the bond pads of adjacent dies using through-silicon vias (TSVs).

A challenge associated with vertically stacked die packages is that the heat generated by the individual dies combines and increases the operating temperatures of the individual dies, the junctions therebetween, and the package as a whole. This can cause the stacked dies to reach temperatures above their maximum operating temperatures ( $T_{max}$ ) in many types of devices and especially as the density of the dies in the package increases.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a semiconductor die assembly configured in accordance with an embodiment of the present technology.

FIG. 2 is a cross-sectional view of a semiconductor die assembly configured in accordance with another embodiment of the present technology.

FIG. 3 is a cross-sectional view of a semiconductor die assembly configured in accordance with yet another embodiment of the present technology.

FIG. 4 is a partially schematic cross-sectional view of a semiconductor die assembly configured in accordance with a further embodiment of the present technology.

FIG. 5 is a partially schematic cross-sectional view of a semiconductor die assembly configured in accordance with a still further embodiment of the present technology.

FIG. 6 is a partially schematic cross-sectional view of a semiconductor die assembly configured in accordance with another embodiment of the present technology.

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FIG. 7 is a schematic view of a system that includes a semiconductor die assembly configured in accordance with embodiments of the present technology.

## DETAILED DESCRIPTION

Specific details of several embodiments of stacked semiconductor die assemblies with a thermal spacer configured to distribute heat and associated systems and methods are described below. The term "semiconductor die" generally refers to a die having integrated circuits or components, data storage elements, processing components, and/or other features manufactured on semiconductor substrates. For example, semiconductor dies can include integrated circuit memory and/or logic circuitry. Semiconductor dies and/or other features in semiconductor die packages can be said to be in "thermal contact" with one another if the two structures can exchange energy through heat. A person skilled in the relevant art will also understand that the technology may have additional embodiments, and that the technology may be practiced without several of the details of the embodiments described below with reference to FIGS. 1-7.

As used herein, the terms "vertical," "lateral," "upper" and "lower" can refer to relative directions or positions of features in the semiconductor die assemblies in view of the orientation shown in the Figures. For example, "upper" or "uppermost" can refer to a feature positioned closer to the top of a page than another feature. These terms, however, should be construed broadly to include semiconductor devices having other orientations.

FIG. 1 is a cross-sectional view of a semiconductor die assembly **100** ("assembly **100**") configured in accordance with an embodiment of the present technology. As shown, the assembly **100** includes a plurality of first semiconductor dies **102a** ("first dies **102a**") arranged in a stack **103** on a thermal spacer **105** carried by a second semiconductor die **102b** ("second die **102b**") and a package substrate **106**. The package substrate **106** can include, for example, an interposer, printed circuit board, or other suitable substrate having electrical connectors **108** (e.g., metal bumps) that connect the assembly **100** to external circuitry (not shown).

The first and second dies **102a** and **102b** (collectively referred to as "dies **102**") can include various types of semiconductor components and functional features, such as dynamic random-access memory (DRAM), static random-access memory (SRAM), flash memory, other forms of integrated circuit ("IC") devices, including memory, processing circuits, imaging components, and/or other semiconductor devices. In various embodiments, for example, the assembly **100** can be configured as a hybrid memory cube (HMC) in which the stacked first dies **102a** are DRAM dies or other memory dies that provide data storage and the second semiconductor die **102b** is a high-speed logic die that provides memory control (e.g., DRAM control) within the HMC. In other embodiments, the dies **102** may include other semiconductor components and/or the semiconductor components of the individual first dies **102a** in the stack **103** may differ. Further, although the stack **103** shown in FIG. 1 includes eight first dies **102a**, in other embodiments the stack **103** can include fewer than eight dies (e.g., three dies, four dies, etc.) or more than eight dies (e.g., ten dies, twelve dies, etc.).

As shown in FIG. 1, the dies **102** can be electrically coupled to one another and the thermal spacer **105** by a plurality of electrically conductive elements **109** disposed therebetween. The electrically conductive elements **109** can have various suitable structures, such as pillars, columns, studs, bumps, and can be made from copper, nickel, solder

(e.g., SnAg-based solder), conductor-filled epoxy, and/or other electrically conductive materials. In selected embodiments, for example, the electrically conductive elements 109 can be copper pillars, whereas in other embodiments the electrically conductive elements 109 can include more complex structures, such as bump-on-nitride structures. In the illustrated embodiment of FIG. 1, the second die 102b is electrically coupled to the package substrate 106 by a plurality of electrical connectors 110 (e.g., metal bumps). In certain embodiments, the electrical connectors 110 can be similar in structure and composition to the electrically conductive elements 109 (e.g., copper pillars).

The first dies 102a and the thermal spacer 105 each include a plurality of vias 112 (e.g., TSVs). The vias 112 are aligned on one or both sides with corresponding electrically conductive elements 109. Beyond electrical communication, the electrically conductive elements 109 can serve as thermal conduits through which heat can be transferred away from the dies 102 (as shown, e.g., by first arrow T<sub>1</sub>). In some embodiments, the assembly 100 can also include a plurality of thermally conductive elements 113 (shown in broken lines) positioned interstitially between the electrically conductive elements 109. The individual thermally conductive elements 113 can be at least generally similar in structure and composition as that of the electrically conductive elements 109 (e.g., copper pillars). However, the thermally conductive elements 113 are not electrically coupled to the dies 102 nor the thermal spacer 105. Instead, the thermally conductive elements 113 can serve as additional thermal conduits through which thermal energy can be transferred away from the dies 102, thereby facilitating additional heat transfer.

The dies 102 and the thermal spacer 105 can be at least partially encapsulated in a dielectric underfill material 115. The underfill material 115 can be deposited or otherwise formed around and/or between the dies 102 and the thermal spacer 105 to electrically isolate the electrically conductive elements 109 and/or enhance the mechanical connection between the dies 102 and the thermal spacer 105. The underfill material 115 can be a non-conductive epoxy paste (e.g., XS8448-171 manufactured by Namics Corporation of Niigata, Japan), a capillary underfill, a non-conductive film, a molded underfill, and/or include other suitable electrically-insulative materials. In some embodiments, the underfill material 115 can be selected based on its thermal conductivity to enhance heat dissipation through the dies 102 and/or the thermal spacer 105.

The thermal spacer 105 can include crystalline, semi-crystalline, and/or ceramic substrate materials, such as silicon, polysilicon, aluminum oxide (Al<sub>2</sub>O<sub>3</sub>), sapphire, and/or other suitable semiconductor materials having high thermal conductivities. The thermal spacer 105, for example, can be an interposer (e.g., a glass or silicon interposer) having passive, active, and/or inactive through-silicon vias. In certain embodiments, the thermal spacer 105 can be similar in shape, size, and/or composition as the second die 102b or the individual first dies 102a. For example, the thermal spacer 105 and the first dies 102a can each include a silicon substrate having the same arrangement of contact features (not shown) and/or type of contact features (e.g., bond pads) on each side of the substrate. In the illustrated embodiment of FIG. 1, the thermal spacer 105 and the stack 103 have the same footprint (i.e., the same planform shape). In other embodiments, the thermal spacer 105 and the stack 103 can have different footprints. For example, the thermal spacer 105 can be larger than the individual first dies 102a along at least one axis. As described in greater detail below, the thermal spacer 105 can

also be configured to have the same footprint as the second die 102b and/or the package substrate 106.

In one aspect of the embodiment of FIG. 1, the thermal spacer 105 is configured to separate the stack 103 from the second die 102b to reduce the concentration of heat at the junction between the stack 103 and the second die 102b. In another aspect of the embodiment of FIG. 1, the thermal spacer 105 is configured to absorb and conduct thermal energy away from the dies 102. In several embodiments, the thermal spacer 105 can transfer heat such that the individual dies 102 operate at lower heat than without the thermal spacer 105. Further, the thermal spacer 105 can lower the operating temperatures of the individual dies 102 such that they stay below their designated maximum temperatures (T<sub>max</sub>). When arranged as a HMC, a larger underlying logic die (e.g., the second die 102b) typically operates at a much higher power level than the stack of memory dies (e.g., the stack 103) above the logic die (e.g., 5.24 W compared to 0.628 W). The logic die, accordingly, radiates a significant amount of heat. The logic die may also have a higher power density toward its periphery that results in a further concentration of heat and temperature rise toward the periphery. In the illustrated embodiment, the thermal spacer 105 does not include IC devices nor other active components, such as memory and logic circuitry. As such, the thermal spacer 105 does not provide any intermediary signal processing (e.g., logic operations, switching, etc.). Instead, the thermal spacer 105 can be configured as a "blank die" or a "blank semiconductor substrate" having only passive electrical conductors (e.g., the vias 112 and/or thermally conductive elements 113) for communicating electrical signals through the substrate of the thermal spacer 105, but without processing any of the signals communicated through the thermal spacer. Because such passive components do not collectively generate as much heat as IC devices or other active components, the thermal spacer 105 produces substantially smaller amounts of heat relative to the dies 102. In certain embodiments, the thermal spacer 105 can have a thickness configured to provide a suitable thermal spacing between the stack 103 and the second die 102b. Accordingly, in several embodiments the thermal spacer 105 can have the same thickness as either the second die 102b or the individual first dies 102a. In other embodiments, the thermal spacer 105 can be thicker or thinner than the dies 102.

The assembly 100 further includes a thermally conductive casing 116 ("casing 116") defining an enclosure 118 (e.g., a cavity, recess, etc.). The casing 116 includes an outer wall 120 extending at least partially around the stack 103. The casing 116 is attached to the second die 102b by a portion of the underfill material 115 in a gap 122 between the outer wall 120 and the second die 102b. In particular, the underfill material 115 in the gap 122 is attached to a forward facing surface 123 toward the periphery of the second die 102b. The casing 116 can serve as a heat spreader to absorb and dissipate thermal energy away from dies 102 and the thermal spacer 105. The casing 116 can accordingly be made from a thermally conductive material, such as nickel, copper, aluminum, ceramic materials with high thermal conductivities (e.g., aluminum nitride), and/or other suitable thermally conductive materials. In certain embodiments, the casing 116 may be at least partially contained within an outer casing 125 (shown in broken lines) attached to the package substrate 106 and further facilitating absorption and dissipation of thermal energy. In other embodiments, the casing 116 can include other configurations and/or structures, such as a heat sink (not shown) with a plurality of fins and/or other surface enhancing structures for enhanced heat dissipation.

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In certain embodiments, the underfill material **115** in the gap **122** can enhance the thermal conductance at the junction between the outer wall **120** and the second die **102b** (as shown, e.g., by second arrow  $T_2$ ). In such a configuration, for example, the outer wall **120** can transfer heat away from the (often higher power density) peripheral portion of the second die **102b**. In other embodiments, another interface material can be used in combination with or in lieu of the underfill material **115** to attach the outer wall **120** to the second die **102b**. Other interface materials can include, for example, a silicone-based grease, gel, or adhesive that is doped with conductive materials (e.g., carbon nano-tubes, solder materials, diamond-like carbon (DLC), etc.), a phase-change material, as well as other suitable thermal interface materials (referred to in the art as a “TIMs”). In some embodiments, for example, an interface material can be made from X-23-7772-4 TIM manufactured by Shin-Etsu MicroSi, Inc. of Phoenix, Ariz., which has a thermal conductivity of about 3-4 W/m<sup>2</sup> K. In other embodiments, the interface material can be made from metals (e.g., copper) and/or other suitable thermally conductive materials.

FIG. 2 is a partially schematic cross-sectional view of a semiconductor die assembly **200** (“assembly **200**”) configured in accordance with another embodiment of the present technology. The assembly **200** can include features generally similar to those of the assembly **100** of FIG. 1. For example, the assembly **200** includes the dies **102** and the thermal spacer **105** stacked relative to one another and interconnected by the vias **112** and the electrically conductive elements **109**. The assembly **200** also includes an additional thermal spacer **205** disposed between the thermal spacer **105** and the second die **102b**. The additional thermal spacer **205** can be similar to the thermal spacer **105** and can include, for example, vias **212** (e.g., TSVs) and electrically conductive elements **209** (e.g., copper pillars) electrically coupling the thermal spacer **105** with the second die **102b**. In one aspect of the embodiment of FIG. 2, the additional thermal spacer **205** can provide additional separation between the second die **102b** and the stack **103**. As discussed above, additional separation can reduce the concentration of thermal energy between the stack **103** and the second die **102b**.

FIG. 3 is a cross-sectional view of a semiconductor die assembly **300** (“assembly **300**”) configured in accordance with yet another embodiment of the present technology. The assembly **300** can include features generally similar to the features of the assembly **100** described above with reference to FIG. 1. For example, the assembly **300** can include the dies **102** and a thermal spacer **305** stacked relative to the dies **102**. In the illustrated embodiment of FIG. 3, the thermal spacer **305** has the same footprint of the second die **102b** along at least one axis. In addition, the assembly **300** further includes an interface material **326** (e.g., a TIM) disposed between the second die **102b** and the thermal spacer **305**. The interface material **326** can be configured, for example, to enhance thermal contact as well as the mechanical connection between the second die **102b** and the thermal spacer **305**.

As shown, the thermal spacer **305** includes a peripheral portion **328** having a forward facing surface **323** attached to the outer wall **120** of the casing **116** via the underfill material **115** in a gap **322** between the outer wall **120** and the thermal spacer **305**. The peripheral portion **328** can extend laterally outward beyond at least one side of the stack **103** (e.g., beyond the length and/or width of the stack **103**). In general, the peripheral portion **328** can be defined by the position of the stack **103** on the underlying thermal spacer **305** and the relative dimensions of the stack **103** and the thermal spacer **305**. As shown, the stack **103** and the thermal spacer **305** are

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centered with respect to one another such that the peripheral portion **328** extends laterally beyond opposite sides of the stack **103**. In other embodiments, the stack **103** may be offset with respect to the center of the thermal spacer **305**. As such, the peripheral portion **328** may extend around less than the full perimeter of the stack **103** and/or the peripheral portion **328** can have a larger footprint at one side of the stack **103** (e.g., the right side) relative to another side of the stack **103** (e.g., the left side). In one aspect of this embodiment, the thermal spacer **305** can facilitate manufacturing in addition to enhancing thermal properties. For example, the forward facing surface **323** of the thermal spacer **305** can provide a generally rigid attachment location for the casing **116**. Further, the thermal spacer **305** can protect the underlying second die **102b** during assembly.

FIG. 4 is a partially schematic cross-sectional view of a semiconductor die assembly **400** (“assembly **400**”) configured in accordance with a further embodiment of the present technology. The assembly **400** can include, for example, features generally similar to the features of the assembly **100** described above with reference to FIG. 1. For example, the assembly **400** can include the dies **102** and a thermal spacer **405** stacked relative to the dies **102**. Instead of being between the stack **103** and the second die **102b**, however, the casing **116** is attached to a peripheral portion **428** of the second die **102b** and the thermal spacer **405** is between the second die **102b** and the package substrate **106**. As shown, the thermal spacer **405** includes a plurality of vias **412** electrically coupled to a redistribution structure **430**. The redistribution structure **430** can include conductive features (not shown), such as traces, metal lines, bond pads, etc., that electrically couple the vias **412** to electrical connectors **410** of the second die **102b**. In one aspect of the embodiment of FIG. 4, the thermal spacer **405** can absorb and dissipate heat at the junction between the second die **102b** and the package substrate **106**. In addition, an interface material **426** (e.g., a TIM) disposed between the second die **102b** and the thermal spacer **405** can enhance heat transfer between the second die **102b** and the thermal spacer **405**.

FIG. 5 is a partially schematic cross-sectional view of a semiconductor die assembly **500** (“assembly **500**”) configured in accordance with a still further embodiment of the present technology. The assembly **500** can include features generally similar to the features described above with reference to FIGS. 1-4. For example, similar to the assembly **400** of FIG. 4, the assembly **500** includes a thermal spacer **505** between the second die **102b** and the package substrate **106** and electrically coupled to the second die **102b** by the electrical connectors **410** and the vias **412**. However, the assembly **500** includes a configuration in which a thermally conductive casing **516** (“casing **516**”) at least partially encloses the second die **102b** within an enclosure **518** of the casing **516**. In addition, the thermal spacer **505** has a larger footprint than the second die **102b** along at least one axis such that an outer wall **520** of the casing **516** can be connected to a peripheral portion **528** of the thermal spacer **505** by an interface material **526** (e.g., a TIM). In some embodiments, an interface material **526** can be positioned between the second die **102b** and the outer wall **520** to enhance thermal contact with the thermal spacer **505**.

FIG. 6 is a partially schematic cross-sectional view of a semiconductor die assembly **600** (“assembly **600**”) configured in accordance with another embodiment of the present technology. The assembly **600** can include features generally similar to those of the assembly **500** of FIG. 5. For example, the assembly **600** includes the thermally conductive casing **516** at least partially enclosing the dies **102** within the cavity

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518 of the casing. The assembly 600 further includes an additional thermal spacer 605 between the second die 102b and the stack 103. Accordingly, in this configuration the thermal spacers 505, 605 can absorb and conduct heat away from opposite sides of the second die 102b.

Any one of the stacked semiconductor die assemblies described above with reference to FIGS. 1-6 can be incorporated into any of a myriad of larger and/or more complex systems, a representative example of which is system 700 shown schematically in FIG. 7. The system 700 can include a semiconductor die assembly 710, a power source 720, a driver 730, a processor 740, and/or other subsystems or components 750. The semiconductor die assembly 710 can include features generally similar to those of the stacked semiconductor die assemblies described above, and can therefore include multiple thermal paths that enhance heat dissipation. The resulting system 700 can perform any of a wide variety of functions, such as memory storage, data processing, and/or other suitable functions. Accordingly, representative systems 700 can include, without limitation, hand-held devices (e.g., mobile phones, tablets, digital readers, and digital audio players), computers, and appliances. Components of the system 700 may be housed in a single unit or distributed over multiple, interconnected units (e.g., through a communications network). The components of the system 700 can also include remote devices and any of a wide variety of computer readable media.

From the foregoing, it will be appreciated that specific embodiments of the technology have been described herein for purposes of illustration, but that various modifications may be made without deviating from the disclosure. For example, although many of the embodiments of the semiconductor dies assemblies are described with respect to HMCs, in other embodiments the semiconductor die assemblies can be configured as other memory devices or other types of stacked die assemblies. In addition, the semiconductor die assemblies illustrated in FIGS. 1-6 include a plurality of first semiconductor dies arranged in a stack on the second semiconductor die. In other embodiments, however, the semiconductor die assemblies can include one first semiconductor die stacked on the second semiconductor die. Certain aspects of the new technology described in the context of particular embodiments may also be combined or eliminated in other embodiments. Moreover, although advantages associated with certain embodiments of the new technology have been described in the context of those embodiments, other embodiments may also exhibit such advantages and not all embodiments need necessarily exhibit such advantages to fall within the scope of the technology. Accordingly, the disclosure and associated technology can encompass other embodiments not expressly shown or described herein.

We claim:

1. A semiconductor die assembly, comprising:
  - a thermally conductive casing having a sidewall, wherein thermally conductive casing defines a cavity;
  - a stack of first semiconductor dies within the cavity;
  - a second semiconductor die mechanically and electrically coupled to the stack of first dies, the second semiconductor die having a face facing the toward the stack of first semiconductor dies, wherein the sidewall of the thermally conductive casing is attached directly to the face of the second semiconductor die by a thermal adhesive;
  - a package substrate carrying the second semiconductor die; and
  - a thermal spacer disposed between the package substrate and the thermally conductive casing, wherein the ther-

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mal spacer includes a semiconductor substrate and plurality of conductive vias extending through the semiconductor substrate and electrically coupled to the stack of first semiconductor dies, the second semiconductor die, and the package substrate.

2. The semiconductor die assembly of claim 1 wherein the thermal spacer is configured to transfer heat such that individual first semiconductor dies operate at a lower heat than without the thermal spacer.

3. The semiconductor die assembly of claim 1 wherein the thermal spacer is configured to electrically couple the second semiconductor die to the stack of first semiconductor dies without processing any signals communicated through the thermal spacer.

4. The semiconductor die assembly of claim 1 wherein the thermal spacer does not include memory nor logic circuitry.

5. The semiconductor die assembly of claim 1 wherein the thermal spacer is disposed within the cavity and between the second semiconductor die and the stack of first semiconductor dies.

6. The semiconductor die assembly of claim 1 wherein the thermal spacer is disposed outside of the cavity and between the second semiconductor die and the package substrate.

7. The semiconductor die assembly of claim 1 wherein the thermal spacer comprises a blank silicon die.

8. The semiconductor die assembly of claim 1 wherein the thermal spacer is disposed in the cavity, and wherein the die assembly further comprises an underfill material at least partially encapsulating the thermal spacer and the stack of first semiconductor dies.

9. The semiconductor die assembly of claim 1 wherein the thermal spacer includes conductive features attached to the plurality of conductive vias at one or more sides of the thermal spacer, and wherein the die assembly further comprises an underfill material at least partially encapsulating the conductive features.

10. The semiconductor die assembly of claim 9 wherein the conductive features are further attached to either the second semiconductor die or the stack of first semiconductor dies.

11. The semiconductor die assembly of claim 1 wherein: the thermal spacer is a first thermal spacer; the semiconductor die assembly further comprises a second thermal spacer stacked relative to and electrically coupled to the first thermal spacer; and the first and second thermal spacers are disposed between the stack of first semiconductor dies and the second semiconductor die.

12. The semiconductor die assembly of claim 1 wherein: the thermal spacer is a first thermal spacer; the semiconductor die assembly further comprises a second thermal spacer stacked relative to and electrically coupled to the first thermal spacer; the first thermal spacer is disposed between the second semiconductor die and the stack of first semiconductor dies; and the second thermal spacer is disposed between the second semiconductor die and the package substrate.

13. A semiconductor die assembly, comprising:
 

- a thermally conductive casing, wherein the thermally conductive casing defines a cavity;
- a stack of first semiconductor dies within the cavity;
- a second semiconductor die mechanically and electrically coupled to the stack of first dies;
- a package substrate carrying the second semiconductor die; and
- a thermal spacer disposed between the package substrate and the thermally conductive casing, wherein the ther-

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mal spacer includes a semiconductor substrate and plurality of conductive vias extending through the semiconductor substrate and electrically coupled to the stack of first semiconductor dies, the second semiconductor die, and the package substrate;

wherein the stack of first semiconductor dies has a first footprint;

wherein the second semiconductor die has a second footprint larger than the first footprint, wherein the second semiconductor die has a peripheral region extending laterally outward with respect to the stack of first semiconductor dies;

wherein the thermal spacer has a third footprint that is at least as large as the first footprint along at least one axis, but no larger than the second footprint along the at least one axis.

**14.** A semiconductor die assembly, comprising:

a logic die having a face;

a memory die stacked relative to the logic die;

a thermally conductive casing extending at least partially around the memory die and at least partially enclosing the memory die within an enclosure, wherein the thermally conductive casing has a sidewall attached directly to the face of the logic die by a thermal adhesive;

a thermal spacer outside of the enclosure, wherein the thermal spacer includes a peripheral portion extending beyond the memory die, and the thermal spacer is configured to carry the thermally conductive casing proximate the peripheral portion.

**15.** The semiconductor die assembly of claim **14** wherein the logic die and the thermal spacer have generally the same planform shape.

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**16.** The semiconductor die assembly of claim **14** wherein the logic die has a generally larger planform shape than the thermal spacer.

**17.** The semiconductor die assembly of claim **14** wherein the logic die is disposed within the enclosure and between the thermal spacer and the memory die.

**18.** The semiconductor die assembly of claim **14** wherein the logic die has a generally larger planform shape than the memory die, but a generally smaller planform shape than the thermal spacer.

**19.** The semiconductor die assembly of claim **14**, further comprising a package substrate configured to carry the thermal spacer, wherein the thermal spacer and the package substrate have generally the same planform shape.

**20.** The semiconductor die assembly of claim **14** wherein the memory die is one of a plurality of memory dies electrically coupled together in a stack.

**21.** A semiconductor system, comprising:

a package substrate;

a thermally conductive casing having a conductive sidewall;

a plurality of semiconductor dies configured to be carried by the package substrate and at least partially disposed within the thermally conductive casing, the plurality of semiconductor dies including a plurality of memory dies, a logic die having a face, and a thermal spacer stacked relative the logic die and the memory dies, wherein the memory dies are stacked relative to the logic die; and

a driver electrically coupled to the plurality of semiconductor dies via the package substrate;

wherein the conductive sidewall is attached directly to the face of the logic die by a thermal adhesive.

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